Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period: \_\_\_\_\_\_\_\_

Calorimeter Design Project & Specific Heat Lab

The purpose of this lab is to engineer a calorimeter that can be used to measure the heat loss from water as it cools, and measure the specific heat capacity of a metal sample. Both experiments will use the same apparatus.

Introduction: Calorimetry is the art of measuring energy. A calorimeter is a device that measures energy flow in a system. For example, determining how many calories are in a cheeseburger is done with a device called a “bomb calorimeter.” A sample of the food is burned in a closed container that is surrounded by water. The energy content of the food is determined from the temperature increase of the water jacket that surrounds the combustion chamber. In order to keep the most kinetic energy (temperature) in the calorimeter it must be well-insulated.

You should take into account when engineering your calorimeter:

☞ The Efficiency (in terms of limiting heat loss)

A calorimeter is designed to minimize heat flow between the inner cup and the outside world. Usually, conduction of heat is eliminated by supporting the inner cup only by the thin, insulating phenolic (a type of plastic) ring, and by providing an insulating air space around the cup. Convection is eliminated by blocking air circulation with the solid ring and the lid. Radiation is eliminated by making the inner cup and outer jacket out of aluminum, which can block infrared radiation.

Possible Materials to be used to construct your calorimeter: Beakers, plastic cups, Styrofoam cups, Tissues, Aluminum Foil, Saran wrap, and other “stuff” that I have in our classroom.

Possible materials that would need to be brought from home: Masking or Duct tape, Socks, Cardboard, Bubble wrap, packing peanuts, Other items (must be approved)

Part I (Day 1). The Prototype Design

A prototype is a model that can be tested and refined in order to meet specifications required of a final product; designing a final product that meets a specific function requires multiple iterations and tests along the way.

**Calorimeter Requirements:**

1. Can hold 100 mL of water
2. Has an opening to leave a thermometer in it
3. Can open to easily drop a block of metal into it
4. Reusable for 5-6 tests
5. Using the materials provided, make a calorimeter.
6. In your notebook, draw a labeled model of your calorimeter.
7. Write a paragraph description of your calorimeter:

* Why did you make the design choices you did?
* What predictions can you make about how the energy transfer from the system to the surroundings will be contained to the calorimeter?

1. Show me your notebook entry for a completion stamp:

Completion Stamp 1: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Part II (Day 2). The Water Test & Redesign

Using water, you will be testing the efficiency of your calorimeter (how “good” it is) by filling it with hot water and measuring the temperature change of that water over time. The less heat lost (lower temperature change) the better your calorimeter design.

Materials: Calorimeter, 100 mL Beaker, Graduated Cylinder, Tongs, Hotplate, Thermometer

1. Measure 50 mL water (use a graduated cylinder) and add it to the beaker. Set the beaker on the hotplate at medium heat. Heat until the temperature is between 70 and 75 ˚C.
2. Using the tongs, pour the water from the beaker into your calorimeter, then set the beaker on the counter to cool. *Do NOT put cold water in a hot beaker or it will shatter!*
3. Record the initial temperature (time = 0). Record the temperature each minute for 5 total minutes. Under the “trial 1” column.

Part II. Data Analysis

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Time (minutes) | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 |
| 0 (initial temperature) |  |  |  |  |  |
| 1 minute |  |  |  |  |  |
| 2 minutes |  |  |  |  |  |
| 3 minutes |  |  |  |  |  |
| 4 minutes |  |  |  |  |  |
| 5 minutes |  |  |  |  |  |

1. What is the rate of temperature loss in your cup in degrees Celsius per minute? (Hint: Take the total change in temperature ÷ 5 minutes)
2. What percent of your heat was lost? (Final Temp – Initial Temp) x 100

Initial Temp

**Compare your rate of change to the other groups in your class.**

1. Which of the containers that you observed has the highest rate of change? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_°C/min

What do you notice about those calorimeters?

>

>

>

1. Which of the containers that you observed has the lowest rate of change? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_°C/min

What do you notice about those calorimeters?

>

>

>

1. How can you incorporate your observations from other groups to improve your calorimeter design? In other words, how can you improve your calorimeter?

>

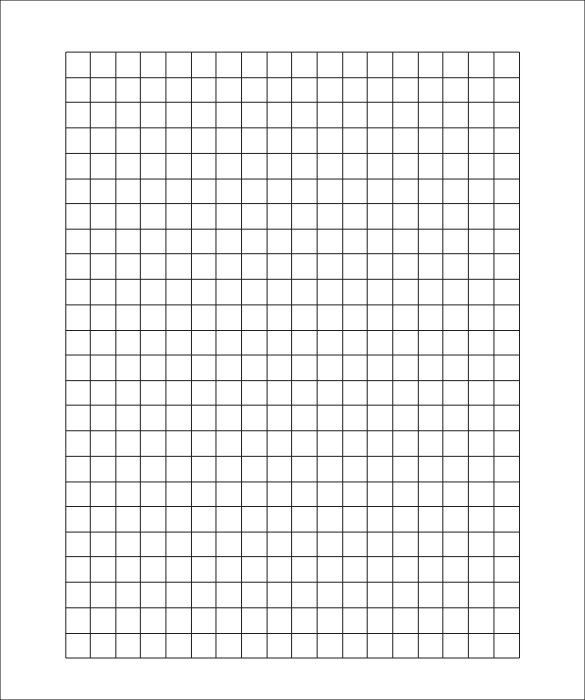
>

>

1. Test your new & improved calorimeter. Record the data under “trial 2”. You may redesign and test as many times as you can before the end of the class!
2. Sketch your improved calorimeter in your notebook and show it to me for a completion stamp.

Completion Stamp 2: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Graph the data from each of your trials. Make each trail a different color. *(No, black pen and pencil do NOT count as “different colors”.)* Make sure your graph **TALKS**!



Part III (Day 3). Specific Heat of a Metal

The heat gained or lost by a substance when it undergoes a change in temperature is calculated as the product of the mass of the substance, its change in temperature, and its specific heat.

According to the law of heat exchange, the total amount of heat lost by a hot object equals the total amount of heat gained by the cold object with which it come in contact. Consequently, in this experiment the total heat lost by the solid on cooling equals the total heat gained by the water and calorimeter as they are warmed.

Materials: Calorimeter, Beaker, Hotplate, Wire/Twine, Tongs, 2 Thermometers, Metal sample

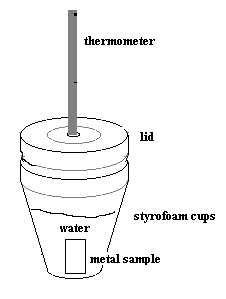
1. Obtain the materials listed above. For the metal sample, record which letter (A or B) you got in the first row of your data table.
2. Measure and record the mass of your metal sample. (get the mass without the string!
3. Attach twine or wire to your metal sample and lower it into a beaker half-filled with water.
4. Place the beaker of water (with the metal in it) on a hot plate and bring it to a full boil
5. While waiting for boiling to occur, weigh the mass of your empty calorimeter and record.
6. Fill the calorimeter 1/2 full with cool water from the sink.
7. Measure the mass of the calorimeter and the water. Record in your data table.
8. You will need to use both of your thermometers at the same time:
   1. Take the temperature of the water in the calorimeter.
   2. Take the temperature of the boiling water (this is the initial temperature for the metal)
9. After measuring the temperature of the boiling water, immediately lift the metal from the boiling

water with the twine or wire and quickly transfer the metal sample to the calorimeter.

1. Gently agitate (stir) the water in the cup—keep the thermometer in the water!
2. Monitor the temperature of the water using the thermometer, when it has risen to its highest point, record it.
3. Repeat steps 3-11 for a second trial.

Part III. Data Analysis & Calculations

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Step |  | Trial 1 | Trial 2 | Average |
| 1 | We have unknown metal \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. (Same for both tests) | | | |
| 2 | Mass of metal (g) |  | |  |
| 5 | Mass of empty calorimeter (g) |  |  |  |
| 7 | Mass of calorimeter and water (g) |  |  |  |
|  | Mass of water alone (g)  (step 7 minus step 5) |  |  |  |
| 8a | Initial temp of cool water  (In calorimeter) (°C) |  |  |  |
| 8b | Initial Temp of hot metal  (temp of boiling water) (°C) |  |  |  |
| 11 | Final temperature of metal  and water (°C) |  |  |  |
|  | ΔT for Water  (step 11 minus step 8a) |  |  |  |
|  | ΔT for Metal  (step 11 minus step 8b) |  |  |  |

1. In the diagram to the right, use arrows to show the flow of heat between the water and metal. Which way was heat transferred?
2. Complete the following statement: The amount of heat the metal \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(gains/loses) as it cools is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (greater than/equal to/less than) the amount of heat the water \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_(gains/loses) as it heats up.
3. Using the averages of the data you collected, calculate the heat gained by the water, Q.

Mass of water = Q = mcΔT

C (specific heat of water) = 4.184 J/g°C

ΔT for water =

1. We know that all of the heat that was absorbed by the water came from the metal—so Qmetal = −Qwater. Using this information and the averages from your data table, calculate the specific heat (c) of the metal.

Q (from question 1) = − Calculate specific heat (c) of your metal:

Mass of metal =

ΔT for metal =

|  |  |
| --- | --- |
| **Metal** | **Specific Heat (J/g °C)** |
| Aluminum | 0.902 |
| Nickel | 0.440 |
| Silver | 0.240 |
| Zinc | 0.390 |

1. Using the table of values, which metal do you think you have? (Based on its specific heat?) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. The actual (accepted) specific heat for your metal sample is: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
3. What is the percent error for your experiment?
4. List two sources of error and explain how they affect your results.